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A Model for Predicting Daily Peak Visitation and Implications for Recreation Management and Water Quality: Evidence from Two Rivers in Puerto Rico

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Abstract Visitor use surveys and water quality data indicates that high visitor use levels of two rivers in Puerto Rico does not appear to adversely affect several water quality parameters. Optimum visitor use to maximize visitor defined satisfaction is a more constraining limit on visitor use than water quality. Our multiple regression analysis suggests that visitor use of about 150 visitors per day yields the highest level of visitor reported satisfaction, a level that does not appear to affect turbidity of the river. This high level of visitor use may be related to the gregarious nature of Puerto Ricans and their tolerance for crowding on this densely populated island. The daily peak visitation model indicates that regulating the number of parking spaces may be the most effective way to keep visitor use within the social carrying capacity.

Keywords Visitation model · Recreation management · Water quality · River visitation · Recreation impact analysis · Visitor satisfaction · Tropical rivers · Turbidity · Environmental carrying capacity · Puerto Rico · Use levels · Social carrying capacity · Peak visitation · Mameyes River · Espíritu Santo River

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Introduction

Public land and recreation managers in densely populated areas are concerned about the impact that an increasing number of visitors is having on: (a) the quality of their recreation experience; and (b) the natural environment at recreation sites, as well as water quality at these sites. Models that consider data on average daily peak visitation may be useful in estimating the factors that influence daily peak use, which has direct relevance for recreation impact analysis. Peak daily visitor estimates provided by the daily model may provide an indication of whether a site is likely to be used beyond its social and environmental carrying capacity, thus allowing for the determination of limiting factors.

Two multiple regression models are estimated to predict and explain daily visitation and level of visitor satisfaction for two watersheds located in northeastern Puerto Rico: the Mameyes and the Espíritu Santo. To further increase the management relevance of these models for evaluating recreation impacts on water quality, we focused on a previously overlooked distinction: counts have been obtained for both visitors recreating in the river and those recreating outside the river.

Predicted visitor use levels and satisfaction measures may serve as indicators of social carrying capacity, while the assessment of water quality impacts may serve as indicators of environmental carrying capacity. Carrying capacity indicators at the Mameyes and Espíritu Santo River sites indicate that social carrying capacity is the limiting factor.

Such estimates may also be helpful in the daily management of forest sites, since daily peak impact analysis could assist managers in assigning daily quotas on visitor use per site. The number of available parking spaces at each river site may prove to be the most important allocation enforcement control variable available to park managers.

Finally, the research also examined the relationship between use levels and visitor satisfaction in the context of densely populated tropical forest rivers. Our findings indicate that Puerto Ricans seem to prefer higher densities than those observed in other United States locations, once again showing that the relationship between crowding and satisfaction is generally weak, and may be dependent on cultural factors.

Review of Carrying Capacity Literature and Models

Increasing demands on recreation facilities in the 1950's led to attention to the use of natural resources. Resulting policy concerns led to the idea of carrying capacity, which can be broadly defined as the ultimate limits to growth as constrained by environmental factors (Odum 1959). Wagar (1951) was one of the first authors to identify carrying capacity as one of eight major principles in recreation land use. Later, the term became more widely used in the articles from the Outdoor Recreation Resources Review Commission (ORRRC 1962). Carrying capacity has also been used in wildlife management, referring to the number of arrivals that could be maintained in a habitat (Dasmann 1964). The term is still widely used in the outdoor recreation literature, and recent institutional directives have made the concept a formal part of outdoor recreation management (Manning et al. 1996). Its usefulness as an outdoor recreation management concept is stressed when used as a framework for determining and managing recreation opportunities.

There is a significant body of work estimating recreation effects on carrying capacity (Manning 1985; Manning et al. 1996; Vaske and Donnelly 2002; Haas 2003; Kneeshaw et al. 2004; Lewin et al. 2006; Thrane 2000). The body of literature examined has focused on the social impact of recreation policies on the environment, and the physical and environmental impacts of visitor use to vegetation, water quality and soil degradation. Figure 1 illustrates the common themes in many of the social carrying capacity discussions.

The top panel of Fig. 1 shows that as visitor use increases, total visitor satisfaction increases, at a decreasing rate, then peaks, and then at very high levels of visitor use, total satisfaction actually falls due to adverse visitor interaction and competition for space at the recreation site. When total satisfaction is at its peak, this is often referred to as the optimum social carrying capacity (CCsoc). The marginal satisfaction curve crosses the horizontal axis in the lower panel. Beyond this point, an additional visitor would cause negative benefits.

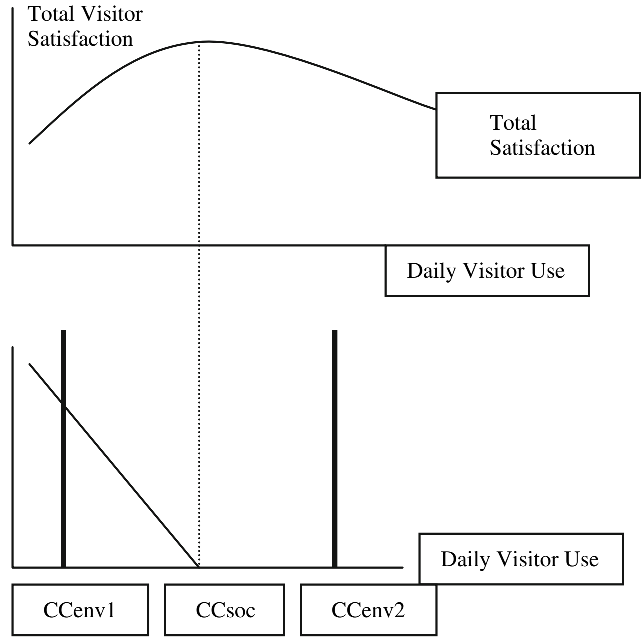

Fig. 1 A conceptual model of social and environmental carrying capacity illustrating when environmental carrying capacity is binding (CCenv1) or not (CCenv2)

However, the social carrying capacity may be larger or smaller than the environmental carrying capacity at the site. For example, if the site is fragile alpine tundra, visitors may be able to tolerate more crowding than the vegetation can sustain. In the example of an alpine environment, the environmental carrying capacity is the limiting factor at CCenv1. However, other sites may be quite resilient and the social carrying capacity may be the limiting factor, rather than the environment. One of the objectives of this article is to determine if the overall carrying capacity of two rivers in Puerto Rico is more limited by social crowding considerations, or by water quality parameters, such as ammonia and turbidity.

A stylized model of the relationship in the top panel of Fig. 1 would be:

$$\begin{aligned}&\text{Visitor Satisfaction}\\&\quad = f(\text{Number of Visitors, Number of Visitors}^2)\end{aligned}$$

This stylized model will form the basis of our empirical model for the two case study rivers.

Recreation Impacts on Environmental Carrying Capacity

An increasing number of visitors in recreational sites may have a direct impact on water quality, ground cover vegetation, and soil degradation. Visitor use can have indirect effects on water quality from eroding the vegetation off stream banks and thus making stream banks more prone to erosion. Also visitors, especially children, can have direct effects on water quality by urinating or dropping food in the stream. Studies report varying degrees of impact to the environment, with some sites recuperating quickly and others requiring a longer time period for indicators to return to previous levels.

Turner and Ruhl (2007) examined phosphorus loadings associated with a park tourist attraction: the Linesville Spillway of Pymatuning State Park in Pennsylvania. Their study demonstrated that fish-feeding activity by park visitors has the potential for local degradation of the aquatic ecosystem. Lakes, streams, and rivers are especially vulnerable to disruptions of nutrient cycles, because they are preferred recreational sites, but are sensitive to small perturbations of biogeochemical cycles. They recommend park managers consider such disruptions to ecosystem level processes when evaluating visitor impacts.

Cole (1989) examined the physical, chemical, and biological qualities of surface waters in and around recreation areas, finding little alteration of water quality from second home development, swimming, use of developed campgrounds, or dispersed recreation use. Hilton and Phillips (1982) examined daily boat impact on turbidity at the River Ant in Great Britain. Their model estimated that turbidity at the river returned to 0–1 FTU within 5.5 h of the cessation of boat movement. Thus, boat impact on turbidity was considered minimal. Hammit and Cole (1998), however, found evidence of water quality alteration due to recreation. The authors found that swimming and other activities can increase turbidity by directly disturbing the lake or stream bed, especially when the substrate is composed of primarily fine sediments.

Effects of trampling on vegetation have been studied more frequently (Cole 1989). Where recreation use is heavy, all ground cover vegetation, except that in protected places, may be eliminated. Case studies of recreation impacts on animals are numerous, but results are often contradictory and highly site- and species-specific.

García and Hemphill (2002) have examined loss of vegetation, reduction in depth of organic horizon, loss of surface organic matter, increased soil bulk density, and reduced infiltration rates. They indicated that these anthropogenic influences may place an aquatic habitat in danger of extinction.

Zabinski et al. (2002) have examined the effect of intensive recreation impacts and restoration amendments on soil parameters at four campsites in the Eagle Cap Wilderness, Oregon. Their results demonstrated that soils on heavily impacted campsites had lower soil nitrogen availability and soil microbial populations. Campsite disturbance of soils resulted in loss of the litter layer and degradation of soil physical structure. The decline in microbial biomass, basal respiration, and carbon utilization profiles suggest that important microbial processes could be greatly slowed in such disturbed soils. The reduced function of soil microorganisms can impact revegetation success both immediately and in the long term.

Andrés-Abellán et al. (2005) examined the effects of recreational use on the soil and vegetation at a site of environmental importance in Albacete, Spain. The most visited sites showed increased soil compaction of approximately 50%, bare ground increase to 61 ± 10%, and a decrease in richness (from 25 ± 2 to 15 ± 2 sp.), diversity (from 4.0 ± 0.1 to 2.7 ± 0.4), and stratification of plant species (from 80 ± 11 to 21 ± 4%). The most visited sites had 90% less plant species as compared to the least visited. Intense use was associated with the presence of nitrophilous plant and vegetal species with a morphology adapted to heavy trampling. The recreational areas showed a distribution pattern of impact radiating outwards from the most used and degraded point. At the most visited point, “Los Chorros” (the spring of the river), the impact radiated outwards for about 20 m. A pilot experiment examining the effects of one-year visitor access restrictions to a formerly impacted area showed a plant cover increase by anthropic, not by native, species of 57%.

Carrying Capacity, Satisfaction, and Crowding

Wagar (1964) considered visitors’ impacts not only to recreation areas, but also to the quality of the recreation experience. Increasing use level was associated with visitor satisfaction, and early models assumed an inverse relationship between both variables. Early studies (Cicchetti 1976; McConnell 1977) cast doubt on the assumed inverse association, and found the relationship between crowding and satisfaction to be weak. The lack of relationship between use level and satisfaction may be related to crowding norms and expectations being shaped by use levels on the site. Areas and activities are self-selected by recreationists to meet preferences and expectations, including those concerning use levels (Stewart and Carpenter 1989). This normative approach suggests that crowding is not interpreted negatively until it is perceived to interfere or disrupt one’s objectives or values (Ditton et al. 1983).

Experience level is also thought to affect normative definitions of crowding either through refinement of tastes or due to exposure to lower-density conditions as a result of earlier participation (Bryan 1977). Crowding judgments can also be influenced by activities being pursued and the settings in which they occur (Cohen et al. 1975).

A nine-point crowding measure has been adopted that allows direct comparisons across studies, areas, and time (Heberlein and Vaske 1977). Shelby et al. (1989) examined findings from 35 studies which included 59 areas and 17,000 visitors. Results indicate that many visitors to recreation areas experience some degree of crowding, which varied across recreational settings, time or season of use, resource availability and accessibility, and management actions.

More recently, Vaske and Shelby (2007) examined perceived crowding using 615 evaluation contexts from 181 studies. All studies used the 9-point scale developed by Heberlein and Vaske (1977). Perceived crowding varied by changing use conditions and management actions. The authors point that their findings are useful for advising natural resource managers on potential carrying capacity problems and providing estimates, even though the measure itself is not sufficient for a complete carrying capacity study (Heywood and Murdock 2002; Vaske and Donnelly 2002; Vaske and Shelby 2007). Manning (1997, 1999), however, suggests the need for multiple measurement approaches. Both survey methods and observations may be useful, since the relationship between visitor attitudes and behavior may be weak. Visual methods are emphasized in high-use areas, but evaluative dimensions of management actions may be appropriate if study data are to be used in setting limits on use.

One relevant concern in the satisfaction literature is stated by the inter-site displacement hypothesis. Visitors less tolerant to crowding may not stay at a heavily visited site, moving to a less crowded alternative. Kuentzel and Heberlein (1992) research contradicted this hypothesis. In a study conducted in the Apostle Islands, those visitors most sensitive to an increasing use of a resource did not necessarily become crowded out or forced to find alternate locations to pursue their recreational interests. Those who stopped boating between 1975 and 1985 did not do so because they felt overcrowded. Annual visitors more than doubled between 1975 and 1985, yet the perception of crowding among boaters decreased. There was an increasing preference for encounters, and it was unexplained by changes in the visitor population. Their data shows that one cannot assume crowding perceptions will increase as visitor numbers increase. Similarly, if visitors' numbers are constant, crowding perceptions may not remain stable.

Study Sites

The following research was conducted at river-road intersections in the Mameyes and the Espíritu Santo watersheds, located in Puerto Rico's northeastern region (see Fig. 2). Three of the interview sites were located within the Caribbean National Forest boundaries, while the remainder site was located close to urban areas outside of the forest.

Areas outside the Caribbean National Forest are closer to the coastal regions, under the authority of the Commonwealth of Puerto Rico and its municipalities. The three municipalities sharing jurisdiction over watershed lands are Rio Grande, Luquillo, and Fajardo. The Commonwealth's Department of Natural and Environmental Resources is also responsible for certain lands closest to the watersheds' rivers and streams.

The Mameyes is one of very few rivers in Puerto Rico to run through most ecosystems present in Puerto Rico, including the rain forest in its higher elevations, the coastal flood plains, wetlands, and mangroves (González-Cabán and Loomis 1997). The river originates at 728 meters (2396 feet) above sea level in the Caribbean National Forest. Its length is estimated at 15.5 kilometers (9.7 miles), and traverses the municipalities of Rio Grande and Luquillo.

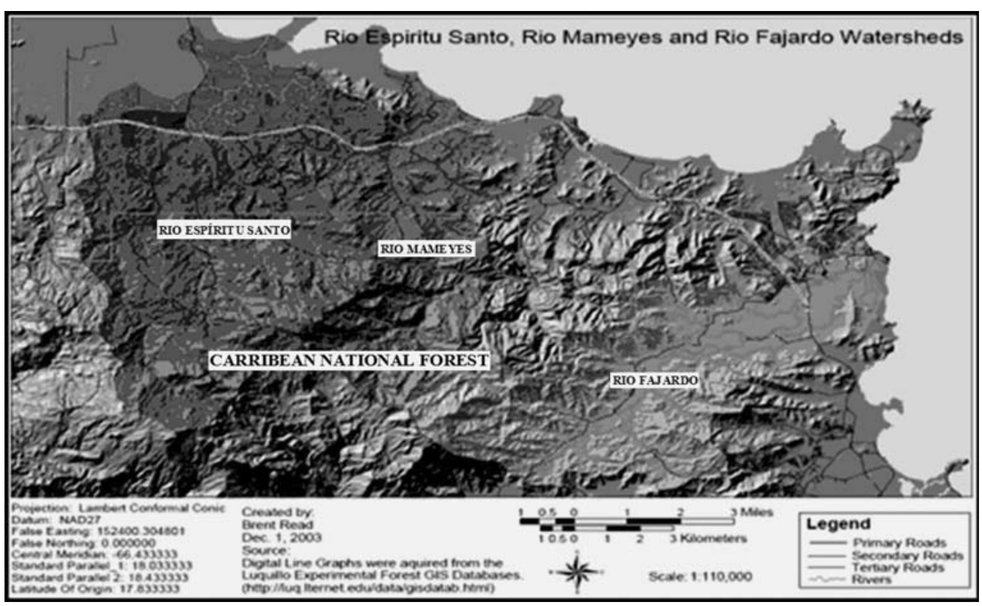

Fig. 2 The Espíritu Santo and Mameyes Rivers watersheds

The Rio Mameyes is also where the USFS Visitor Center is located, and is the more well known of the two rivers in Puerto Rico, attracting local visitors as well as tourists from outside Puerto Rico. The Espíritu Santo, on the other hand, is visited mostly by local residents.

The Espíritu Santo begins at an altitude of 740 meters (2435 feet) above sea level. It traverses the municipality of Rio Grande a distance of 19.2 kilometers (12 miles), until it reaches the Atlantic Ocean. Its watershed covers an area of 41.9 square kilometers. The geology of the watershed is mainly volcanic in origin, covering an estimated area of 38.1 squared kilometers (14.7 square miles).

Both watersheds originate in the Caribbean National Forest (CNF), the only tropical rainforest within the USDA Forest Service National Forest system, with a land area of approximately 11,336 hectares (28,000 acres). The CNF contains over 240 species of native trees, of which 88 are rare and 23 are only found in the forest. There are also 127 species of terrestrial vertebrates and ten species of aquatic invertebrates. The CNF is the habitat of five endangered species and one threatened species. In its rivers and other bodies of water, one can find a variety of shrimp and fish species (such as Macrobrachium carcinus and Agonostonoms monticola), as well as river crabs (Epilobocera sinuatifrons). Its highest peak is 1077 meters (3533 feet) above sea level, and its mean temperature is 21°C (73°F). There are four main forest types, considering climate, soil, slope, and tree species variations: Tabonuco, Palo Colorado, Palma de Sierra and Bosque Enano. Both rivers are characterized by bedrock stream bottoms and lush tropical forest canopy. Both the Mameyes and Espíritu Santo rivers have many small pools for wading and sitting in, some of which have sufficient stream current to provide "hydromassage," similar to a Jacuzzi.

A relevant management concern for this area is the high level of visitor use on the rainforest ecosystem, particularly the streams and rivers. Puerto Rico's average population density in 2005 was estimated at 440.8 inhabitants per square kilometer, or 1125.3 inhabitants per square mile (American Community Survey 2005), so usage of recreation facilities is perhaps more intensive than what may be experienced in other United States National Forest areas. The following research will focus on maximum daily river visitation predictions, and examine visitation impact on the average user's level of satisfaction and site water quality.

Data Collection

Project researchers first evaluated both the Espíritu Santo and Mameyes watersheds to identify potential river recreation sites where public roads crossed the rivers thus providing visitor access. After researchers conducted several initial visits to various watershed locations, 26 sampling sites were identified, 13 in each of the two rivers. After eliminating seven zero-visitation sites because of their remote location, eleven potential visitation sites were identified in the Espíritu Santo, and nine in the Mameyes. Even though some of these sites were still believed to have zero-visitation, they were included as part of the sample to verify that in fact there was no visitation at those locations. A total of eight potential zero visitation sites were finally identified; five at the Espíritu Santo, and three at the Mameyes watershed.

Data collection was carried out during the months of July and August of 2005. We conducted sampling during these two months because traditionally very few residents of Puerto Rico visit the rivers outside of these two summer months. This low visitation was confirmed by periodic visits prior to commencing our full sampling effort. Given our budget, it was not cost effective to sample in what would be very low use months. From the standpoint of environmental carrying capacity, the low use months are not likely to be of concern. Likewise, social carrying capacity is likely not a concern in the low use months. Management concerns regarding visitor satisfaction and water quality is thus during these two peak use months.

An adult from every visitor group was approached at the site by one of two interviewers. Thus, our sample is close to a census of all groups of visitors at the site that day. The interviews were in-person while visitors were recreating at the river. The interviewers were trained graduate and undergraduate students who closely followed a script. While refusals to be interviewed were not tracked, (a limitation of the study), discussion with interviewers indicate there were less than a dozen refusals. Given the 790 completed interviews, the refusal rate was about 1%, and hence the survey response rate is 99%.

The prediction of peak daily use may be particularly useful in the process of determining a region's social and environmental carrying capacity. Visitor prediction is estimated with a daily visitation time step model. The dependent variable in the model is defined as the maximum daily number of visitors per site, which can be further subdivided into the average or maximum total number of visitors, although for carrying capacity estimations, the maximum figure was used. The daily model includes independent variables that describe physical site characteristics, whether natural or built. These variables were elevation, pool volume, and number of available parking spots.

To determine if there was a relationship between peak visitor use and visitor satisfaction, the maximum number of visitors per site were then introduced as an explanatory variable in our second model, whose purpose was to predict the visitor's level of satisfaction. One might expect a quadratic relationship between visitor use and satisfaction. Some people might feel safer recreating in the river if there are others around. Also, given the gregarious nature of the Puerto Rican people, picnicking and wading in rivers, particularly on holidays, is often viewed as a party or celebration rather than a pursuit of solitude. However, at a high enough level of crowding, the relationship may become negative, as space in the river and along the shoreline for people can become limited. A second relevant independent variable in the maximum daily visitation model was site elevation, a physical site characteristic. It is important to note that higher elevation sites were usually located within the Caribbean National Forest, where visitors can find more heavily forested areas with scenic beauty. These locations are also generally farther away from urban centers and more heavily congested highways.

Results

General Visitor Use Patterns

Seasonal estimates of the number of visitors in and out of the river were derived from the daily data, using a sampling expansion factor. A season was defined as the four summer months of May through August. We developed seasonal visitation estimates for sites at the Espíritu Santo River. During the summer of 2005, we estimated a total of 5324 visitors. Of the total, 2071 visitors (39%) were recreating in the river and 3253 visitors (61%) recreating outside the river.

We also developed seasonal visitation estimates for sites at the Mameyes River. For the summer season of 2005 a total of 12727 visitors were estimated; this is more than double the number observed for the Espíritu Santo. Estimates of in-river and out-of-river seasonal recreation visitation at the Mameyes show a more even division. An estimated 52% of total visitors recreate in the river.

Daily Visitation Model Results

The unit of analysis in the daily visitation model is not only the 19 sites, but each day of sampling; therefore, the number of observations and, hence, degrees of freedom is 59. The daily visitation model is specified according to the following equation:

$$\begin{aligned}\text{Max\#of Daily Visitors} = \text{Bo} & + \text{B}_1(\text{Number of Parking Spots}) \\ & + \text{B}_2(\text{Elevation}) \\ & + \text{B}_3(\text{Pool Volume}) \\ & + \text{B}_4(\text{NumParkHoliday})\end{aligned} \tag{1}$$

Where the Number of Parking Spots is a measure of parking capacity at each site; Elevation of the site is measured in feet and included as a control variable to allow us to combine data across river sites; Pool volume represents the volume of the largest pool at the recreation site; we expect sites with larger pools would be attractive to more visitors; and NumParkHoliday is a variable that estimates the effect of additional visitors per car during the holidays, where levels increase significantly. It is an interaction variable defined as the product of the number of parking spots and the holiday dummy variable. On a holiday, the variable acquires the value of the number of parking spots, and on nonholidays, the NumParkHoliday value is zero. The equation estimation results using the Least Squares Method are shown in Table 1.

The influence of the number of parking spots is positive and significant at the 5% level, as expected. Available parking, a management control variable, appears to be an essential determinant of the maximum number of daily visitors at a site. The second variable, NumParkHoliday, was also positive and significant at the 5%, as expected, given that the number of visitors during the three July holidays (July 4th, 17th, and 25th) was significantly higher, on average, than the levels observed on weekdays, or even weekends, indicating higher number of people per vehicle during holidays.

Site elevation is also positive and significant at the 5% level, confirming the notion that higher altitude sites are more heavily visited given their natural beauty and distance from crowded urban centers and highways. Overall the model explained nearly one-third (32%) of the variation observed in daily peak visitation to our 19 sites.

Two-thirds of the variation remains unexplained. Our data gathering included a comprehensive list of site-specific, user-specific, and climate variables which were not significant in the explanation of maximum daily visitor variation. Location-specific variables included road class/width, pool size, scenic views, accumulation of litter, and the presence of restaurants nearby. Respondents reported their family income, age, education level, travel time, travel cost, and gender. Climate variables, measured during the interview process, included presence of rain and temperature at the site. None of the previous possible

Table 1 Maximum number of daily visitors per site

Variable	Coefficient	Standard error	*t*-statistic	*p*-Value
Constant	−8.0352	8.9539	−0.8974	0.374
Number of Parking Spots	0.1674	0.0838	1.9963	0.051
Elevation	0.0427	0.0209	2.0403	0.046
Pool Volume	0.0150	0.0116	1.2971	0.200
NumParkHoliday	0.3376	0.1690	1.9982	0.051

explanatory factors were significant in the forecast of number of daily visitors, pointing to the difficulty in developing a comprehensive model. The visitor model, though somewhat lacking in explanatory power, is able to provide managers with three variables that contribute to the explanation of visitor variation at river sites.

Level of Satisfaction Model Results

The Level of Satisfaction model attempts to explain the relationship between the maximum visitor use levels at a site and their level of satisfaction during their visit:

$$\begin{aligned}&\text{Average Visitors' Perceived Level of Satisfaction}_{it}\\&= \text{Bo} + \text{B}_1\left(\text{Maximum Number of Visitors in the River}_{it}\right)\\&+ \text{B}_2\left(\text{Square of the Maximum Number of Visitors}\right.\\&\qquad \left.\text{in the River}_{it}\right)\\&+ \text{B}_3\left(\text{Elevation}_i\right)\end{aligned}$$

The dependent variable was an average on the sampling day (t) of visitor reported satisfaction at site i where i=1,2,3...11. The satisfaction scale of 1 to 10 was used to estimate how enjoyable was the recreation experience, one being the least enjoyable, and 10 being the most enjoyable.

Users' perceptions of satisfaction at a location were explained in the second model by the maximum number of daily visitors, as shown by the positive and significant visitation coefficient. A term representing the square of the visitation values was also included to test whether there was an inflexion point where the level of satisfaction began to decrease due to high site visitation levels. Since we are pooling data across several river sites that are located at different elevations, site elevation was included to control for variables correlated with elevation.

The equation estimation results using the Least Squares Method are shown in Table 2. The quadratic term was statistically significant at the 10% level. Finally, site elevation was positive and significant at the 10% level; a higher site location would seem to indicate a higher average perceived visitor level of satisfaction at a given site. Elevation is positively correlated to scenic views and negatively correlated to road width; both relationships may help to explain the positive elevation coefficient in the perceived level of satisfaction model. While the individual coefficients are statistically significant, the r^2 is just 15%, consistent with the literature that many other factors also influence visitor satisfaction.

Figure 3 shows the fitted statistical relationship between a Visitor's Perceived Level of Satisfaction and the Maximum Number of Visitors in the River derived from the regression coefficients in Table 2. Elevation was set at the mean of the data for all sites at 215 meters. The curve plots the average level of visitor satisfaction compared to the average number of visitors in the river each day at a recreation site. The visitor nine-point satisfaction scale was compressed to draw attention to the point at which a decrease in satisfaction occurs with visitor increase. Visitor satisfaction rises with visitor use up to the point of 150 visitors per day. As maximum river visitation goes beyond a level of 150 visitors, the perceived level of satisfaction begins to decrease. High levels of other visitors in northeastern river recreation sites in Puerto Rico may be seen as a signal to other visitors to stop at the site and recreate. This could be explained in part by at least two factors: (a) the nature of the primary recreation activities that visitors engage in at the site; and (b) the gregarious nature of Puerto Rican culture; conditioned probably by the smallness of the island and limited recreation site opportunities.

Based on survey results, the most frequently mentioned activity was visiting with family and friends (79% of the visitors interviewed). The fourth most popular activity was also social in nature: picnicking, eating, and drinking (40% of the visitors interviewed). These are clearly human centered activities, in which the presence of others, particularly, extended family and friends is a desirable feature. Only a small fraction of the visitors participated in activities that emphasized introspection (e.g., spiritual renewal was only 11%) or where physical interference from too many others would be problematic, i.e., nonmotorized boating was engaged in by less than 1% of the visitors.

Table 2 Visitors' perceived level of satisfaction

Variable	Coefficient	Standard error	*t*-statistic	*p*-Value
Constant	7.3665	0.3522	20.9170	0.000
Max R Num Visitors	0.0256	0.0110	2.3255	0.024
Max Num Visitors Q	−9.65E-05	5.63E-05	−1.7132	0.093
Elevation	0.0018	0.0010	1.7782	0.081

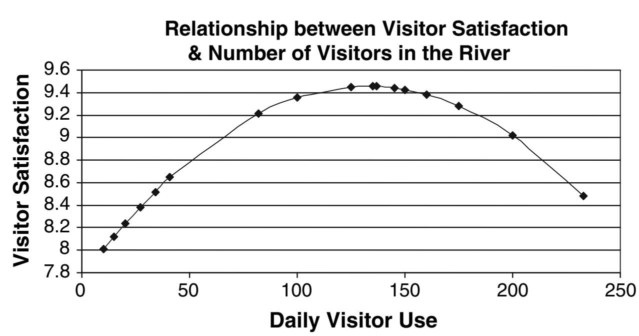

Fig. 3 Relationship between visitors' perceived level of satisfaction and maximum visitation at a river site

This visitor use social carrying capacity peak at 150 visitors is relatively high compared to western US river recreation where visitor satisfaction begins to decline with 5–25 visitors encountered. However, the rate of decline in visitor benefits falls fairly slowly on some of these western US rivers, with positive benefits still evident at 150–200 visitors per day (Loomis and Walsh 1997). Manning (1997) examined a list of more than thirty studies where the number of visitor encounters served as an indicator of the quality of the recreation experience. Even though peak visitation statistics were unavailable, average daily figures at river recreation sites were much lower than the peak carrying capacity observed in the Mameyes and Espíritu Santo Rivers.

Our results in Puerto Rico are consistent with the literature on Hispanic preferences for recreation elsewhere. In particular, Hispanics tend to recreate in large family groups rather than individually (Dwyer and Barro 2001) and significantly choose group activities and picnicking as compared to Anglos (Baas et al. 1993). Their decision making is group oriented rather than individualistic (Lopez et al. 2005; Floyd 1999).

Recreation Impacts on Water Chemistry and Turbidity

Given the high level of visitation observed at the sampled recreation sites, researchers hypothesized that there would be a negative effect on water quality and turbidity at the most heavily visited sites. Scatena (2007) examined water quality effects at the La Mina recreation site, located on the Mameyes River within the Caribbean National Forest. Water chemistry analysis included Ammonium (NH_4), Nitrates (NO_3), Dissolved Organic Nitrogen (DON) and Total Nitrogen (TN). In Fig. 4, the letter A represents water quality samples taken above or upstream from the visitation site, and the letter B indicates results obtained below or downstream from heavy visitation. Figure 4 shows a comparative analysis of water chemistry both upstream and downstream from the area where visitor use is concentrated.

While the presence of swimmers at the recreation site did result in minor measurable increases in ammonium, dissolved organic nitrogen, and total nitrogen, there were statistically insignificant differences between upstream and downstream locations, as evidenced by the overlap in confidence intervals from samples above and below visitation. Even in the case of ammonium (from urine) there is an overlap of confidence intervals. But most importantly, the water pollution levels were within accepted water quality standards. For instance, the ammonium concentration observed downstream meets the EPA standard for drinking water. On the Río Mameyes, in spite of heavy visitor use, water quality improved significantly before reaching downstream water intakes.

High visitation levels also have the potential to result in high turbidity levels. Hein (2007) examined turbidity levels at the recreation sites identified in both the Mameyes and Espíritu Santo watersheds during the summer of 2005. Water quality samples were taken twice daily on the same days as the visitor counts and visitor surveys took place.

The diamonds represent data points from the nineteen recreation sites. The highest observation at El Verde in the Río Espíritu Santo reflected the influence of an upstream flood event, rather than visitor use which was only 5 people. As shown on Fig. 5, even when the visitation numbers are high (more than 200 visitors), there is little increase in sediment, because most recreation sites have a bedrock bottom, and there is little sediment to be stirred up with increased use. One possible explanation is that visitors select sites with clear water and bedrock rather than silt/muddy bottoms for recreation purposes. A bedrock stream bottom allows recreationists to move about with minimal effects on turbidity.

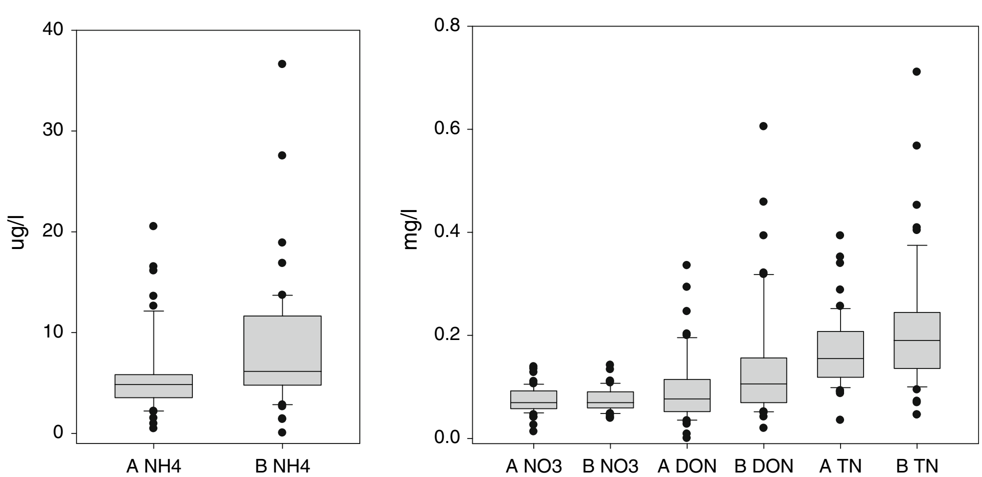

Fig. 4 Analysis of water quality in La Mina, Río Mameyes, Caribbean National Forest

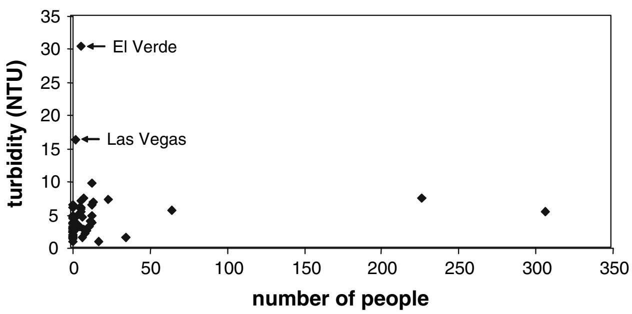

Fig. 5 Turbidity levels at Mameyes and Espíritu Santo watershed recreation sites

Thus, the social carrying capacity at 150 visitors in the river per day would be the constraining factor, not water chemistry or turbidity at the recreation areas along the Río Espíritu Santo and the Río Mameyes. It is also interesting to note that the correlation between amount of litter at the recreation site and visitor use is more influenced by whether there is regular trash collection than it is by visitor use levels. Sites with regular trash collection had less litter, irrespective of visitor use levels (detailed analysis is available from the senior author).

Management and Policy Implications

Empirical analysis of water quality at these recreation sites suggests the high levels of use at the popular sites are not adversely affecting water quality. In particular, Hein's (2007) analysis of turbidity in relation to recreation use finds no statistically significant relationship between visitor use levels and turbidity levels. This lack of relationship appears to be related to the fact that visitors select portions of the river to recreate at that have bedrock river bottoms, rather than silty river bottoms. Given the bedrock river bottom, large numbers of visitors do not stir up much sediment because the parent material is mostly solid rock. Similarly, Scatena (2007) finds that recreation use at the La Mina site, located on the Mameyes watershed, only results in minor increases in ammonia concentrations, as compared to unvisited upstream areas. These minor increases in ammonia concentrations are not statistically significant compared to the upstream control site, and the ammonia concentrations are well below water quality standards. This result appears due to the rainforest rivers having adequate current and flushing flows. Thus, on these two Caribbean National Forest streams, it appears that the concentration of visitor use, rather than spreading, does not appear to result in adverse water quality effects. In addition, Scatena and Marcial's (2006) research indicates there is a lack of spatial and temporal overlap of river users and shrimp in the river channel. This is due to shrimp migration occurring mostly at night, and being inactive during the day, resting in areas of the river not favored by recreation users. Thus, concentrating use at the popular sites does not appear to have the potential to adversely affect shrimp populations. Potential adverse effects on vegetation have not been studied.

Social carrying capacity seems to be the limiting factor at the Caribbean National Forest river sites. Satisfaction indicators are therefore important in this context. The Perceived Level of Satisfaction Model shows that sites must reach a high level of crowding (approximately 150 visitors) before the visitors' level of satisfaction begin to decrease. This model would allow managers to control or redistribute the number of visitors per site.

The daily model can help to partially explain peak visitation levels considering two main physical site characteristics, one built, the number of parking spots, and a second one natural, site elevation. As measured in the case of the daily model, the parking spots near a given recreation location are of particular interest, given that these constitute a management control variable. If the number of available spaces is increased or decreased, peak visitation levels can be altered. That is a variable that site managers can regulate to influence visitor satisfaction and reduce site impacts. The daily visitor models generate predictions and simulations that help inform decisions on desired parking and visitation levels. Some of the informal measures that can be used to restrict parking include making parking spaces larger to reduce the number of spaces or placing large rocks to block certain informal parking areas near sites, as well as posting and enforcing parking regulations in the areas. During peak periods, it may be necessary to station a park ranger to restrict parking to suitable spots or turn away visitors. This is currently done on other heavily visited sites on the Caribbean National Forest sites.

The social custom that other visitors are a positive attribute attracting even more visitors may result in potential future high intensity environmental impacts at the popular sites, for instance, during drought conditions. Whether this is better for the environment than the social custom in which presence of other visitors' causes a shift in use to other less crowded sites is an empirical question and subject to debate in the recreation literature. Concentration of impacts at the few popular "sacrifice sites" reduces impacts at the other sites. Spreading the use out more evenly at all river recreation sites might reduce total environmental impacts, while increasing the visitors' reported level of satisfaction at heavily crowded locations.

A limitation of the study was omission of tracking on-site refusals to be interviewed. This should be recorded in future surveys, and interviewer observations of groups refusing noted so that any patterns in refusing groups can be identified (e.g., teenagers).

Extension of our research would include sampling water quality at these rivers during drought times, when the low flows may not be able to absorb or neutralize impacts of heavy visitor use. Sampling at early season and late season holiday periods (e.g., Memorial Day and Labor Day weekends) would also assist in determining if water quality effects are different during these peak use periods of time.

Further examination of the relationship between crowding and satisfaction in our context would include an analysis of user acceptability levels, measures of gregariousness, and an evaluation of security at the sites. The current data set has only allowed us to analyze the relationship between visitor satisfaction and use levels. Adapting a Norm Curve to conditions in heavily used, small sites would require use instead of encounter levels. User acceptability data would allow for Norm Curve comparability with previous studies. It would also be valuable to collect panel data on security indicators as well as user perceptions of safety at the sites; gregariousness may be related to site safety concerns. Informal visitors may not feel safe in a solitary river site, and a minimum number of visitors may be required to achieve an acceptable level of satisfaction.

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